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Modelling the changes in marine ecosystem and carbon cycle after the K/Pg boundary event

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The mass extinction occurred at the Cretaceous/Paleogene (K/Pg) boundary event, approximately 66 million years ago, which resulted in global-scale biotic turnover that was ecologically diverse but selective. This extinction coincides with both the activities of Deccan Traps volcanism spanning approximately one million years and a large asteroid impact which formed the Chicxulub crater on the Yucatan Peninsula, Mexico. These two events and their environmental and biological consequences left a global imprint in the deep-sea sediments. Deep-sea sediment records indicate the collapse of the oceanic bottom-to-surface gradient of carbon isotope ratio and the carbonate compensation depth (CCD) deepening for several hundred thousand years after the K/Pg boundary. The collapse of the carbon isotope gradient has been variously interpreted as changes in biological production, including a global shutdown of primary production, reduced export production, and enhanced spatial heterogeneity. However, these interpretations remain insufficiently tested for consistency with the geological records. The pronounced long-term decline of carbonate mass accumulation rates (MAR) after the K/Pg boundary is also indicated from deep-sea records. This suggests the necessity of a prolonged reduction in biological carbonate productivity. However, existing boron isotope-based ocean surface pH reconstructions do not support prolonged and severe ocean acidification, making it difficult to explain the long-term decrease of carbonate MAR.

Here, we first investigate changes in marine biological productivity and particulate organic matter (POM) decomposition rate using a vertical one-dimensional ocean carbon cycle model to interpret the collapse of the vertical carbon isotope gradient. We find that, provided POM production and burial persist in coastal regions, the collapse can be explained by either reduced export productivity in the open ocean or reduced POM sinking rates, but cannot discriminate them from the modeling of this study with existing data. These results support the discussion of Kump (1991) and the Living Ocean hypothesis (e.g., D'Hondt et al., 1998). In this model, the CCD deepened, but carbonate production rate was comparable to previous modelling studies, and we were unable to reproduce the pronounced long-term decline of carbonate MAR after the K/Pg boundary event.

Next, we explore an alternative explanation for the long-term decline in carbonate MAR based on changes in the structure of primary producers. At the K/Pg boundary, calcareous nannoplankton, such as coccolithophores, experienced catastrophic extinction, whereas non-calcifying phytoplankton, such as diatoms, were relatively resilient. In addition, enhanced diatom

productivity has been suggested for several hundred thousand years following the K/Pg boundary in the South Pacific. Therefore, climate change and ocean eutrophication following the K/Pg boundary may have favored diatom primary production at the expense of carbonate production by calcareous nannoplankton, but its quantitative contribution remains poorly constrained. We will distinguish calcareous nannoplankton and diatoms by their physiological characteristics and explore how background environmental changes sustain enhanced diatom abundance and reduced carbonate production.